Cancer Imaging (2004) **4,** S1–S7
DOI: 10.1102/1470-7330.2004.0052

CI

e-med
www.e-med.org.uk

KEYNOTE LECTURE

Tuesday 12 October 2004, 08:30–09:00

Multimodality imaging of testicular tumours

Janet E Husband and Dow-Mu Koh

Academic Department of Diagnostic Radiology, Royal Marsden Hospital, Downs Road, Sutton, Surrey, SM2 5PT, UK

Corresponding address: Janet Husband, Academic Department of Diagnostic Radiology, Royal Marsden Hospital, Downs Road, Sutton, Surrey, SM2 5PT, UK. E-mail: janet.husband@icr.ac.uk

Abstract

Testicular tumours are an important group of tumours because the majority are curable. Imaging with computed tomography is pivotal to patient management but other techniques including magnetic resonance imaging, ultrasound and plain films are also useful for staging and follow-up. Positron emission tomography with 18-fluoro-2-deoxyglucose has a growing and unique role in the management of testicular cancer.

Keywords: *Non-seminomatous germ cell tumours; seminoma; residual masses; nodal metastases; lung metastases.*

Introduction

Imaging plays a pivotal role in the management of testicular tumours by establishing the presence and extent of metastatic disease at the time of diagnosis, by assessing response to treatment in those with demonstrable metastatic disease and by evaluating suitability for resection of residual masses. It is also valuable for detecting sites of relapse in patients with early disease on surveillance and in those who have previously been treated.

The most important imaging techniques utilised in the management of testicular tumours are computed tomography (CT) and plain chest radiographs; magnetic resonance imaging (MRI) and ultrasound also have a place in certain clinical situations. There is a growing body of evidence to indicate that positron emission tomography with 18-fluoro-2-deoxyglucose (^{18}F-FDG-PET) and PET/CT can provide unique information in well defined clinical situations.

Incidence and aetiology

The vast majority of testicular tumours are of germ cell origin and are an important group of neoplasms because most of them are curable. They are the commonest malignant tumour in males between the ages of 15 and 45 years but may occur at any age from childhood to the sixth or seventh decade. In the UK there were 1990 new cases in 1999[1].

The incidence of testicular cancer varies widely depending on geographic distribution and race. The highest incidence rates are in Denmark, Norway, Switzerland, Germany and Australia[2,3]; in the USA and the UK intermediate rates are seen. Over the last three decades the incidence of testicular cancer has been rising markedly in all these areas and in the UK approximately one in 500 males will develop testicular cancer[1,2].

There is a much lower incidence of testicular malignancy in Asia, Africa and in North American blacks[4]. The aetiology of testicular cancer is largely unknown but predisposing factors include:

- Amplification of the short arm chromosome 12[5].
- Cryptorchidism: there is an increased risk of between 5 and 20% compared to the risk in individuals with normal testes[6].
- Infantile hernias[5].
- Carcinoma *in situ*: the majority of patients shown to have carcinoma *in situ* in the contralateral testis to the primary tumour will develop a metachronous tumour; carcinoma *in situ* has an increased incidence in patients with undescended testes[7].

Pathology

Ninety-five percent of testicular tumours are germ cell tumours (GCT), 4% are lymphoma and 1% are rare tumours such as Sertoli cell tumours, interstitial (Leydig cell) tumours and paratesticular embryonal sarcomas.

GCT account for 95% of all testicular neoplasms and are classified into non-seminomatous germ cell tumours (NSGCT) (approximately 40–45%), seminomas (approximately 40–45%) and mixed tumours (approximately 10%). There are two main classifications used in the histopathological examination of testicular tumours, the World Health Organization (WHO) system[8] and the British Testicular Tumour Panel classification[9]. The British Testicular Tumour Panel classification is widely used in the UK and Australia but the WHO classification is commonly used in North America and Europe.

Seminoma consists of sheets of large cells with hyperchromatic nuclei. This tumour is often associated with infiltration of lymphocytes and trophoblastic giant cells which produce human chorionic gonadotrophin (HCG) in 15–20% of tumours.

NSGCT occur at an earlier age, usually in the second or third decade. These tumours may consist of more than one cell type which include:

- Malignant teratoma undifferentiated (MTU) (embryonal carcinoma).
- Malignant teratoma differentiated (MTD) (teratoma).
- Malignant teratoma intermediate (MTI).
- Malignant teratoma trophoblastic (choriocarcinoma), yolk sac tumour.
- Malignant teratoma intermediate (mixed GCT).

Elements of trophoblastic teratoma are usually associated with undifferentiated teratoma, but tumours consisting of pure trophoblastic teratoma can occur. These latter tumours metastasise widely and produce very high levels of HCG. Yolk sac elements produce alpha-fetoprotein (AFP) and in children this is the most common variety of GCT. MTI may contain MTU and a variety of other elements, and mixed GCT may also contain elements of seminoma[2].

Serum markers

The normal adult concentration of AFP in the blood is less than 15 ng/ml but it is raised in up to 65% of patients with NSGCT. HCG is elevated in up to 60% of patients with advanced NSGCT tumours but in only 10–20% of patients with clinical Stage I disease[10]. HCG may also be elevated in patients with pure seminoma. Lactate dehydrogenase (LDH) is raised in the majority of patients with advanced NSGCT and seminoma[10].

Patterns of tumour spread

Testicular tumours spread by lymphatic and vascular invasion. Lymphatic spread occurs along four to eight efferent lymphatic channels, which pass from the mediastinum of the testis through the internal inguinal ring accompanying the spermatic cord. These lymphatics join up to form major lymphatic channels which accompany the testicular vessels to enter the retroperitoneal lymph nodes.

Left-sided tumours spread first to the left para-aortic nodes, just below the renal vessels, and the pre-aortic nodes (Fig. 1(a)). Right-sided tumours spread to the interaortico-caval nodes, the precaval nodes and the right paracaval and retrocaval nodes (Fig. 1(b)). Contralateral lymph node involvement in the absence of ipsilateral node involvement is very rare[11]. Crossover to contralateral nodes is also unusual when ipsilateral nodes are less than 2 cm in diameter. Rarely the lymphatic pathway of tumour spread is directly to nodes lateral to the paracaval para-aortic group, the so-called ‘echelon’ node which was first described by the anatomist Rouvière (Fig. 2)[12].

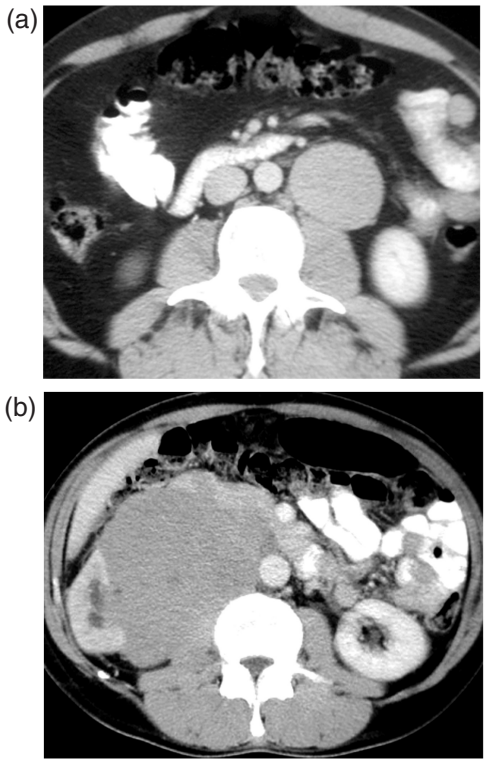

Figure 1 **Two different patients with testicular tumours. (a) Left-sided seminoma showing nodal metastasis in the left para-aortic region. (b) Right-sided non-seminomatous germ cell tumour showing involvement of interaortico-caval nodes and right para-aortic nodes.**

Direct spread to iliac or inguinal nodes alone is rare and usually associated with an identifiable anomaly, e.g. cryptorchidism. Pelvic nodes may become involved in the

presence of bulky retroperitoneal lymphadenopathy due to retrograde flow of lymph resulting from obstruction by tumour.

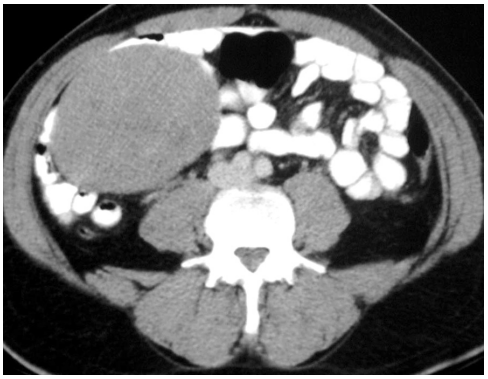

Figure 2 **Large mass involving the 'echelon' node in a patient with seminoma.**

Lymph node disease spreads in a logical manner from the para-aortic nodes to the retrocrural lymph nodes and then to the mediastinum. Direct spread through the diaphragm from the retroperitoneal space leads to posterior mediastinal and subcarinal nodal involvement whereas spread via the thoracic duct may lead to involvement of the supraclavicular nodes and superior mediastinal prevascular nodes.

The first site of haematogenous spread is usually the lungs. Multiple small metastases in a peripheral location are typical features of NSGCT but in seminoma, pulmonary metastases tend to be larger. Other sites of disseminated disease include the brain, bone and liver but any organ may be involved. Brain metastases are more common in patients with trophoblastic teratomas than any other histological type[13].

Staging classifications

In 1996 the stage groupings of the American Joint Committee on Cancer (AJCC) and the Union Internationale Contre le Cancer (UICC) were revised and this new system has now been adopted by both organisations[14]. The new system takes account of tumour volume as well as the sites of metastatic spread. The Royal Marsden system is used widely in the UK and Europe (Table 1) and has been approved by the European Organization for Research and Treatment of Cancer (EORTC)[15,16].

Clinical features and treatment options

Patients with testicular tumours present with a variety of clinical features including testicular pain, swelling or an obvious mass. Occasionally, a patient may present with symptoms due to metastatic disease, e.g. backache due to retroperitoneal lymphadenopathy.

The vast majority of patients with GCT are now eminently treatable and cure rates in excess of 95% can be achieved with multi-agent chemotherapy. Even in patients with advanced disease, cure can be expected in 70–80% of cases[2,5,16,17].

Table 1 The Royal Marsden Hospital staging classification for testicular GCT

Stage	Definitions
I	No evidence of metastases
IM	Rising serum markers with no other evidence of metastases
II	Abdominal node metastases
A	<2 cm in diameter
B	2–5 cm in diameter
C	>5 cm in diameter
III	Supradiaphragmatic node metastases
M	Mediastinal
N	Supraclavicular cervical axillary
O	No abdominal node metastases
ABC	Node size defined as in Stage II
IV	Extralymphatic metastases
	Lung
L1	≤3 metastases
L2	>3 metastases all <2 cm in diameter
L3	>3 metastases, one or more >2 cm in diameter
H+	Liver metastases
Br+	Brain metastases
Bo+	Bone metastases

NSGCT

In the USA, NSGCT Stage I disease, which accounts for approximately 70% of all NSGCT, is frequently treated by retroperitoneal lymph node dissection. This strategy is based on the fact that even with current CT staging, about 30% of patients judged to be Stage I preoperatively actually harbour metastatic disease[18]. Retroperitoneal lymphadenectomy is curative in the majority of patients and surgical mortality is less than 1%. However, serious complications may ensue, such as haemorrhage and pulmonary emboli in the short term, and in the longer term ejaculatory failure and infertility are frequent complications. Recently nerve-sparing surgical procedures have been introduced but nevertheless significant problems persist[19].

Another approach to Stage I disease is surveillance in which patients are followed up rigorously during the first 2 years after diagnosis to identify the 25–30% of patients who will inevitably relapse with metastatic disease. These can be cured with chemotherapy[20]. Of these most will relapse during the first year (80%) and therefore rigorous follow-up during this period is required. Surveillance involves frequent monitoring with serum markers, chest radiographs and CT. The frequency and timing of follow-up scans is under investigation.

Another option for treatment of Stage I disease is two courses of chemotherapy immediately after orchidectomy. The choice of surveillance or adjuvant chemotherapy is made on the basis of risk factors which include the presence of vascular invasion on histological specimens (approximately 50% of cases).

In order to determine the most appropriate therapy for patients with metastatic disease these patients may be divided into high- and low-risk groups. The EORTC factors which define high risk are[21]:

- Elevated AFP greater than 1000 international units.
- HCG greater than 10,000 international units.
- Bone or liver metastases.

The standard treatment for metastatic NSGCT is cisplatin-based chemotherapy which has an overall cure rate of approximately 85%[22]. Staging and tumour bulk influence the exact choice of treatment regimen, with more intensive chemotherapy being used for large-volume disease.

In patients with NSGCT, residual masses following chemotherapy are seen in approximately 25% of cases[23]. These masses frequently contain differentiated teratoma or may consist purely of fibrosis, necrosis and haemorrhage; in approximately 15–20% active malignancy is found. Since the presence of active residual disease is currently impossible to predict, post-chemotherapy lymphadenectomy is performed in patients with retroperitoneal residua greater than 1 cm. Resection of residual masses at other sites, such as the mediastinum and lung, is also performed[24].

Although the majority of patients have an excellent prognosis, about 10–15% with Stage II–IV disease fail standard combination chemotherapy. This group has an overall survival rate of between 20 and 30% and new approaches to therapy including more intensive chemotherapy schedules as well as high-dose therapy with haemopoietic stem-cell rescue are being evaluated[25].

Seminoma

The standard treatment for Stage I seminoma (about 70% of seminomas) is radiotherapy to the para-aortic region. Results are excellent with only about a 2–3% relapse rate[26].

In patients with metastatic seminoma radiotherapy is the standard treatment for small-volume disease, i.e. Stage IIa and IIb disease, but in patients with bulky retroperitoneal stage tumours, chemotherapy is the preferred option.

Imaging

Staging

Computed tomography

The effective use of CT scanning relies on detailed knowledge of the patterns of tumour spread, the characteristic appearances of metastatic disease, and awareness of diagnostic pitfalls.

Lymph node metastases vary in size from a single node of less than 2 cm in diameter to large masses. Small-volume nodes are usually of soft tissue density. Most bulky seminomatous masses are of soft tissue density but occasionally they contain areas of relatively low density due to central necrosis. Large-volume masses of NSGCT are, however, usually heterogeneous containing haemorrhagic areas as well as areas of cystic change and necrosis.

The diagnosis of large-volume disease is readily made on CT, but the diagnosis of small-volume metastatic disease may be difficult.

The effect of size criteria on diagnostic accuracy of CT is an important issue and has been addressed in several studies over the years[27–29]. At the Royal Marsden Hospital a retroperitoneal node greater than 10 mm (maximum transverse diameter) is deemed definitely metastatic, whereas a node between 8 and 10 mm in diameter is considered suspicious. The distinction between enlarged and normal nodes is complicated by the fact that normal nodes are larger in the lower retroperitoneum than in more cranial CT sections.

The need to verify the presence of a nodal metastasis will depend upon the overall assessment of patient's disease. Serum marker estimations are also helpful in determining the need for treatment. Elevated serum markers which fail to regress normally following orchidectomy indicate Stage IM disease and the patient will require treatment irrespective of whether the site of involvement has been identified.

There are various well known pitfalls in the diagnosis of retroperitoneal lymphadenopathy. These include vascular anomalies:

- Large gonadal veins.
- Duplication of the inferior vena cava.
- Left-sided inferior vena cava.
- Retro-aortic and circumaortic renal vessels.
- Left ascending lumbar communicating veins.

Other problems in the diagnosis of lymphadenopathy relate to loops of unopacified bowel which may even be seen between the aorta and inferior vena cava or in the left para-aortic region.

There is some controversy regarding the need to scan the pelvis as well as the abdomen as part of the staging investigation in testicular cancer patients. Involvement of iliac and inguinal nodes is uncommon and is usually associated with congenital anomalies[6]. It can be argued that routine scanning of the pelvis in Stage I patients on surveillance is unwarranted unless predisposing factors are present because this practice subjects the patient to unnecessary irradiation[30].

Thoracic CT is the most sensitive technique for the detection of pulmonary metastases and may also identify nodal spread to the supraclavicular fossa and mediastinum. Although tiny lung nodules less than 3 mm in diameter can be demonstrated on CT, a frequent problem is determining whether these lesions do in fact represent metastases. One practical approach is to rescan the patient after an interval of 4–6 weeks to determine whether there has been any change in size. In this situation spiral CT (multi-slice or single-slice CT) is particularly important as it reduces the errors resulting from mis-registration of CT slices due to irregularities in breath holding. Positron emission tomography (^{18}F-FDG-PET) also has an important role in the diagnosis of equivocal lung lesions.

CT examination of the brain is only indicated in patients at high risk and in patients with suspected metastatic brain involvement on clinical grounds. Brain metastases are usually haemorrhagic and are evident as lesions of high attenuation on unenhanced scans. They usually show contrast enhancement following intravenous injection.

Metastases in other sites, such as the liver and bone, may be missed if these regions are not carefully reviewed on the staging scans and this is particularly relevant in patients with obvious advanced disease in common sites of spread. Furthermore it is important to question every abnormality visible on follow-up scans and to refer to previous CT studies in the same patient so that subtle sites of relapse are not overlooked.

Chest radiography

Plain chest radiography continues to play a valuable role in the management of testicular cancer because lung metastases can be recognised above 1 cm in diameter and assessed for changes in size during follow-up. Mediastinal masses can be evaluated as well as pleurally-based tumour deposits and pleural effusions. Plain chest films are also useful for the detection of pulmonary complications of therapy, such as infection.

Magnetic resonance imaging

The role of MRI in the management of testicular cancer is limited and although it is likely to be equally as accurate as CT in the detection of retroperitoneal nodal metastases, its use is constrained by the lack of availability. MRI is also more expensive than CT and examination of the lungs is not a practical option. However, since MRI has the advantage of not utilising X-radiation the technique may have a place in the imaging strategy of testicular cancer patients who require multiple follow-up examinations.

Current indications for the use of MRI include the detection of brain metastases and the diagnosis of suspected meningeal disease or spinal cord involvement. MRI is useful for the detection of soft tissue musculoskeletal metastases based on its superior contrast resolution. Also MRI can be helpful in the detection and characterisation of focal liver lesions and in detecting suspected bone involvement[31]. Major vessel involvement, such as invasion of the inferior vena cava, can be well shown by the technique[32]. MRI of the testis can distinguish seminomas from NSGCT preoperatively but is less frequently used than ultrasound[33].

Ultrasound

Ultrasound is used as a problem-solver in testicular tumour patients. For example, ultrasound may provide critical information in patients who present with metastatic disease in whom an occult primary tumour of the testis is suspected, and may also identify the small number of patients with bilateral synchronous tumours[34].

Ultrasound is useful in the investigation of focal liver lesions when staging CT is equivocal. Ultrasound is also useful for guidance of biopsy of large retroperitoneal masses, liver lesions or masses in other sites. However, the retroperitoneum is difficult to visualise due to overlying bowel gas and intra-abdominal fat and is therefore not suitable for assessment or biopsy of small retroperitoneal lesions.

Positron emission tomography

Positron emission tomography (PET) scanning is not undertaken as a routine staging investigation in patients with testicular tumours. However, evidence is emerging which suggests that ^{18}F-FDG-PET may identify disease not detected on staging CT. It may therefore have a valuable role in defining the site of relapse in patients with elevated markers but a normal CT examination. Early reports suggest that PET shows advantages with respect to sensitivity compared to CT but specificity is probably similar[35,36]. The inclusion of PET in the management of patients with testicular cancer has been shown to alter management in up to 57% of cases.

Monitoring therapeutic response

The purpose of CT during follow-up is to document the response to therapy as judged by the reduction in tumour volume (Fig. 3) and to delineate the presence and extent and sites of residual disease. In NSGCT patients with demonstrable residua are often treated with surgical excision of residual masses. In patients with large residual masses or multiple sites of residual disease, surgery may be impossible or may need to be carried out in stages. A combined thoraco-abdominal approach to resect both lung and intra-abdominal lesions may be performed in specialised centres. Both CT and MRI have an important role in determining the operability of these complex residual masses and in planning the surgical approach.

In seminoma, surgery is not generally undertaken for residual disease because the vast majority of residua do not contain active cancer.

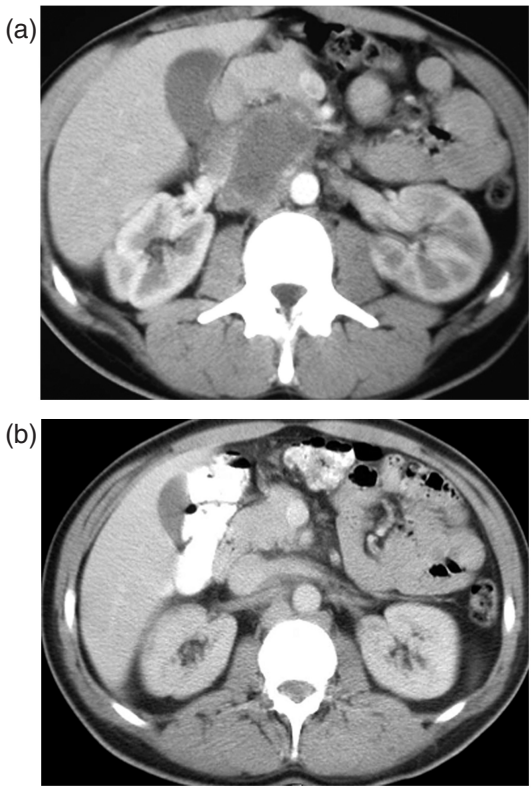

Figure 3 **Partially cystic and partially solid mass in a patient with a non-seminomatous germ cell tumour. (a) Before treatment. (b) Following chemotherapy the mass has almost completely resolved.**

Following therapy for NSGCT masses may become cystic and if so they may enlarge[37]. Simple residual cysts with no soft tissue nodules in the wall usually represent differentiated teratoma whereas residual masses which are partially solid and cystic often contain undifferentiated active cancer as well as areas of necrosis, fibrosis and differentiated tissue. Soft tissue residua may contain active cancer or be entirely benign but there is no way of distinguishing these pathologies on CT. Pure seminoma is highly sensitive to therapy. In seminoma, residual masses usually contain only fibrosis and necrosis and frequently show foci of calcification. In the retroperitoneum the residual mass is usually closely applied to the aorta and inferior vena cava[38].

In the lungs small pulmonary metastases usually show complete resolution on CT. However, scars and cavitation may also be found[39].

^{18}F-FDG-PET can show a reduction in the uptake of tracer before changes in tumour size have occurred and therefore this newer modality is already providing unique information in those centres where it is readily available (Fig. 4). Positive and negative predictive values in excess of 90% have been reported in the evaluation of residual masses[40,41]. Early reports have suggested that ^{18}F-FDG-PET is better at predicting treatment response to high-dose chemotherapy after two or three cycles than cross-sectional imaging or serum tumour marker monitoring.

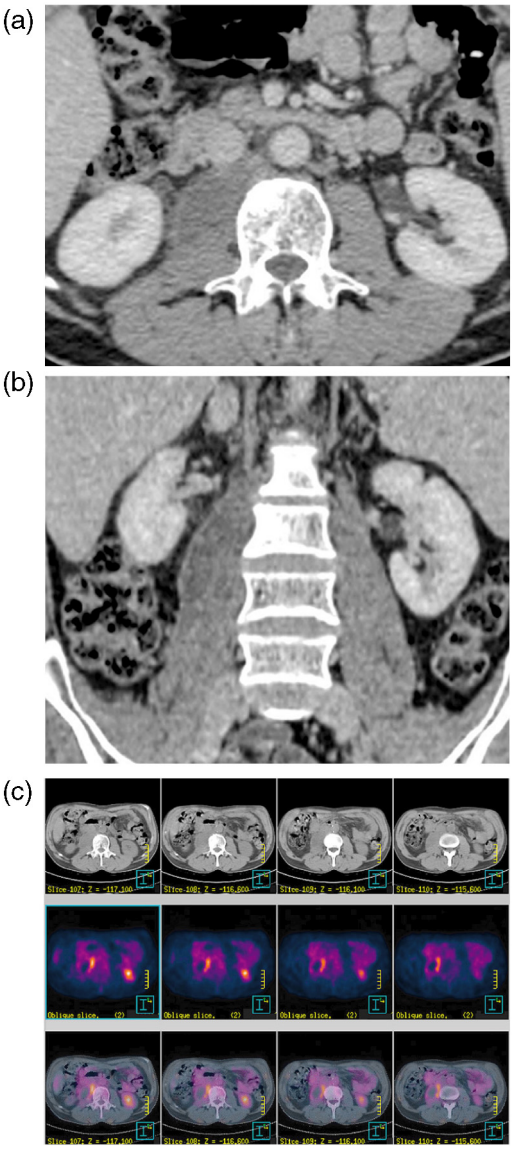

Figure 4 **(a, b) CT demonstrating a large residual mass involving right retroperitoneal nodes, the psoas muscle and the vertebral body of L2. (c) PET/CT clearly shows uptake of ^{18}F-FDG in the mass indicating probable residual active disease after treatment.**

Conclusion

Multimodality imaging of testicular tumours has evolved dramatically during recent years with the advent of multislice CT, MRI and now ^{18}F-FDG-PET imaging. All these techniques frequently have a direct impact on patient management but CT remains the most important modality for staging and follow-up of patients with metastatic disease.

References

[1] CancerStats UK Incidence—April 2003. Cancer Research UK, 2003.

[2] Horwich A, ed. Testicular Cancer: Investigation and Management, 2nd edn. London: Chapman and Hall, 1996.

[3] Stone JM, Cruickshank DG, Sandeman TF, Matthews JP. Trebling of the incidence of testicular cancer in Victoria, Australia (1950–1985). Cancer 1991; 68: 211–9.

[4] Moul JW, Schanne FJ, Thompson IM *et al*. Testicular cancer in blacks. A multicenter experience. Cancer 1994; 73: 388–93.

[5] Dearnaley D, Huddart R, Horwich A. Regular review: managing testicular cancer. Br Med J 2001; 322: 1583–8.

[6] Batata MA, Chu FC, Hilaris BS, Whitmore WF, Golbey RB. Testicular cancer in cryptorchids. Cancer 1982; 49: 1023–30.

[7] Berthelsen JG, Skakkebaek NE, von der Maase H, Sorensen BL, Mogensen P. Screening for carcinoma in situ of the contralateral testis in patients with germinal testicular cancer. Br Med J (Clin Res Ed) 1982; 285: 1683–6.

[8] Mostofi FK, Sesterhenn IA. Revised international classification of testicular tumours. In: Germ Cell Tumours, Appleyard I , ed. Oxford: Pergamon, 1994: 153.

[9] Pugh RCB. Pathology of the Testes, Oxford: Blackwell, 1976.

[10] Mason MD. Tumour markers. In: Testicular Cancer: Investigation and Management, 2nd edn. Horwich A , ed. London: Chapman and Hall, 1996: 35–51.

[11] Dixon AK, Ellis M, Sikora K. Computed tomography of testicular tumours: distribution of abdominal lymphadenopathy. Clin Radiol 1986; 37: 519–23.

[12] Rouvière H. Anatomy of the Human Lymphatic System (translation edited by Tobias MJ), Ann Arbor, MI: Edwards Brothers, 1938.

[13] Husband JE, Koh D-M. Testicular germ cell tumours. In: Imaging in Oncology, vol. I, Chapter 19, 2nd edn. Husband JE, Reznek RH , eds. London: Taylor & Francis, 2004: 401–27.

[14] Greene FL, Page DL, Fleming ID *et al* eds. AJCC Cancer Staging Handbook. TNM Classification of Malignant Tumours, 6th edn. New York: Springer-Verlag, 2002.

[15] Peckham MJ, Barrett A, Liew KH *et al*. The treatment of metastatic germ-cell testicular tumours with bleomycin, etoposide and cis-platin (BEP). Br J Cancer 1983; 47: 613–9.

[16] Stoter G, Sleyfer DT, ten Bokkel Huinink WW *et al*. High-dose versus low-dose vinblastine in cisplatin-vinblastine-bleomycin combination chemotherapy of non-seminomatous testicular cancer: a randomized study of the EORTC Genitourinary Tract Cancer Cooperative Group. J Clin Oncol 1986; 4: 1199–206.

[17] Williams SD, Birch R, Einhorn LH, Irwin L, Greco FA, Loehrer PJ. Treatment of disseminated germ-cell tumors with cisplatin, bleomycin, and either vinblastine or etoposide. N Engl J Med 1987; 316: 1435–40.

[18] Freedman LS, Parkinson MC, Jones WG *et al*. Histopathology in the prediction of relapse of patients with stage I testicular teratoma treated by orchidectomy alone. Lancet 1987; 2: 294–8.

[19] Donohue RE, Mani JH, Whitesel JA, Augspurger RR, Williams G, Fauver HE. Intraoperative and early complications of staging pelvic lymph node dissection in prostatic adenocarcinoma. Urology 1990; 35: 223–7.

[20] Thompson PI, Nixon J, Harvey VJ. Disease relapse in patients with stage I nonseminomatous germ cell tumor of the testis on active surveillance. J Clin Oncol 1988; 6: 1597–603.

[21] Bajorin D, Katz A, Chan E, Geller N, Vogelzang N, Bosl GJ. Comparison of criteria for assigning germ cell tumor patients to good risk and “poor risk” studies. J Clin Oncol 1988; 6: 786–92.

[22] Dearnaley DP, Horwich A, A’Hern R *et al*. Combination chemotherapy with bleomycin, etoposide and cisplatin (BEP) for metastatic testicular teratoma: long-term follow-up. Eur J Cancer 1991; 27: 684–91.

[23] Tait D, Peckham MJ, Hendry WF, Goldstraw P. Post-chemotherapy surgery in advanced non-seminomatous germ-cell testicular tumours: the significance of histology with particular reference to differentiated (mature) teratoma. Br J Cancer 1984; 50: 601–9.

[24] Hendry WF, A’Hern RP, Hetherington JW, Peckham MJ, Dearnaley DP, Horwich A. Para-aortic lymphadenectomy after chemotherapy for metastatic non-seminomatous germ cell tumours: prognostic value and therapeutic benefit. Br J Urol 1993; 71: 208–13.

[25] Bower M, Newlands ES, Holden L, Rustin G, Begent RH. Treatment of men with metastatic non-seminomatous germ cell tumours with cyclical POMB/ACE chemotherapy. Ann Oncol 1997; 8: 477–83.

[26] Zagars GK. Management of stage I seminoma: radiotherapy. In: Testicular Cancer: Investigation and Management, 2nd edn. Horwich A , ed. London: Chapman and Hall, 1996: 99–122.

[27] Lien HH, Stenwig AE, Ous S, Fossa SD. Influence of different criteria for abnormal lymph node size on reliability of computed tomography in patients with non-seminomatous testicular tumor. Acta Radiol Diagn (Stockh) 1986; 27: 199–203.

[28] Stomper PC, Fung CY, Socinski MA, Jochelson MS, Garnick MB, Richie JP. Detection of retroperitoneal metastases in early-stage nonseminomatous testicular cancer: analysis of different CT criteria. AJR Am J Roentgenol 1987; 149: 1187–90.

[29] Forsberg L, Dale L, Hoiem L *et al*. Computed tomography in early stages of testicular carcinoma. Size of normal retroperitoneal lymph nodes and lymph nodes in patients with metastases in stage II A. A SWENOTECA study: Swedish-Norwegian Testicular Cancer Project. Acta Radiol Diagn (Stockh) 1986; 27: 569–74.

[30] White PM, Howard GC, Best JJ, Wright AR. The role of computed tomographic examination of the pelvis in the management of testicular germ cell tumours. Clin Radiol 1997; 52: 124–9.

[31] Arnold PM, Morgan CJ, Morantz RA, Eckard DA, Kepes JJ. Metastatic testicular cancer presenting as spinal cord compression: report of two cases. Surg Neurol 2000; 54: 27–33.

[32] Ng CS, Husband JE, Padhani AR *et al*. Evaluation by magnetic resonance imaging of the inferior vena cava in patients with non-seminomatous germ cell tumours of the testis metastatic to the retroperitoneum. Br J Urol 1997; 79: 942–51.

[33] Johnson JO, Mattrey RF, Phillipson J. Differentiation of seminomatous from nonseminomatous testicular tumors with MR imaging. AJR Am J Roentgenol 1990; 154: 539–43.

[34] Grantham JG, Charboneau JW, James EM *et al*. Testicular neoplasms: 29 tumors studied by high-resolution US. Radiology 1985; 157: 775–80.

[35] Hain SF, O’Doherty MJ, Timothy AR, Leslie MD, Partridge SE, Huddart RA. Fluorodeoxyglucose PET in the initial staging of germ cell tumours. Eur J Nucl Med 2000; 27: 590–4.

[36] Cremerius U, Wildberger JE, Borchers H *et al*. Does positron emission tomography using 18-fluoro-2-deoxyglucose improve clinical staging of testicular cancer? Results of a study in 50 patients. Urology 1999; 54: 900–4.

[37] Husband JE, Hawkes DJ, Peckham MJ. CT estimations of mean attenuation values and volume in testicular tumors: a comparison with surgical and histologic findings. Radiology 1982; 144: 553–8.

[38] Williams MP, Naik G, Heron CW, Husband JE. Computed tomography of the abdomen in advanced seminoma: response to treatment. Clin Radiol 1987; 38: 629–33.

[39] Charig MJ, Williams MP. Pulmonary lacunae: sequelae of metastases following chemotherapy. Clin Radiol 1990; 42: 93–6.

[40] De Santis M, Bokemeyer C, Becherer A *et al*. Predictive impact of 2-18fluoro-2-deoxy-D-glucose positron emission tomography for residual postchemotherapy masses in patients with bulky seminoma. J Clin Oncol 2001; 19: 3740–4.

[41] Sugawara Y, Zasadny KR, Grossman HB, Francis IR, Clarke MF, Wahl RL. Germ cell tumor: differentiation of viable tumor, mature teratoma, and necrotic tissue with FDG PET and kinetic modeling. Radiology 1999; 211: 249–56.